Chapter 5
RESULTS OF HYDROLOGIC ANALYSES

SYSTEMWIDE EFFECTS

Large-scale effects of alterations were analyzed through the use of models. The Natural Systems Model (NSM), as described in **Appendix D**, was used to simulate predevelopment conditions in the watershed. Other basin-scale analyses, based on Hydrologic Systems Program Fortran (HSPF) modeling (**Appendix C**), were used to estimate current (1995 Base Case) conditions.

The overall effects of structural changes in the watershed on flows to the St. Lucie Estuary is depicted in **Table 11**. This table shows the results of using the various models to determine present and historic flows from five tributaries and direct inflow into the estuary. The present day average flows (1965 to 1995) are based on the 1995 Base Case and the estimated historical flows are based on NSM.

Table 11. Summary of Flows to the St. Lucie Estuary for the 1965-1995 Period of Simulation for NSM and 1995 Base Case Based

Model Run	North Fork	C24	C23	C44	South Fork	Direct Inflow	TOTAL
Average Annual Values (acre-feet per year)							
NSM	271,584	9,540	7,781	8,363	82,138	88,486	467,892
1995 Base	165,417	127,520	167,298	88,739	64,203	40,371	653,549
Average Annual Values (cfs)							
NSM	1,475	52	42	45	446	481	2,541
1995 Base	898	692	909	482	349	219	3,549
Average Annual Values (inches per year)							
NSM	6.60	0.23	0.19	0.20	2.00	2.15	11.37
1995 Base	4.02	3.10	4.07	2.16	1.56	0.98	15.89
Average Annual Values (percent of NSM)							
1995 Base	61	1,337	2,150	1,061	78	46	140
Average Annual Values (percent of total)							
NSM	58	2	2	2	18	19	100
1995 Base	25	20	26	14	10	6	100

As indicated, flows to the remaining “natural” streams, the North Fork and South Fork of the St. Lucie River, have declined from 272,000 to 165,000 acre-feet per year (39 percent reduction) and from 82,000 to 64,000 acre-feet per year (22 percent reduction), respectively, and direct inflow has been reduced by about 46 percent from 88,000 to 40,000 acre-feet per year. Discharges to the channelized tributaries C-44, C-23, and C-24 have increased by factors of 11, 22, and 13, respectively.

This increase in channelized flow from C-23, C-24, and C-44 canals has increased total discharges to the estuary by 40 percent. The apparent decreases in flows from the North Fork, South Fork, and "direct inflow" are due primarily to channelization of streams and wetlands, filling of wetlands, and overall decline of the water table.

Further analysis of flow data (**Figure 14**) indicates that the increased flow occurs primarily in the form of increased duration and frequency of high flow events (above 2,000 cfs). In addition, flow has become more variable, as indicated by more flow events in the range from 500 to 1,500 cfs.

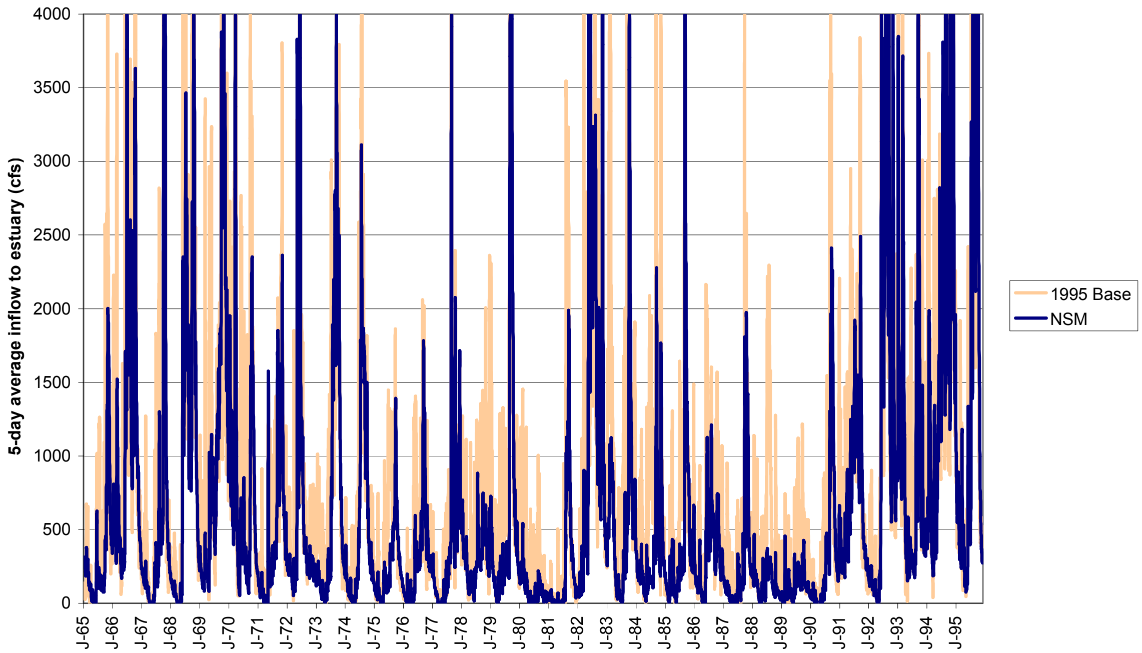

Figure 14. NSM and 1995 Base Case Flows to the St. Lucie Estuary for the 31-Year Period from 1965-1995 (25 occurrences of near-zero flow)

Another way to examine discharge is through the use of a frequency distribution curve as shown in **Figure 15**. When flows for the 1995 Base Case are compared with flows predicted by the NSM, it can be seen that the curve for the 1995 Base Case is shifted to the right.

The overall 40 percent increase in flows to the estuary (**Table 11**) is reflected at all rates of flow. For example for the NSM simulation, about 35 percent of flows to the estuary were above 500 cfs, whereas for the 1995 Base Case, 55 percent of the flows were above 500 cfs (**Figure 15**).

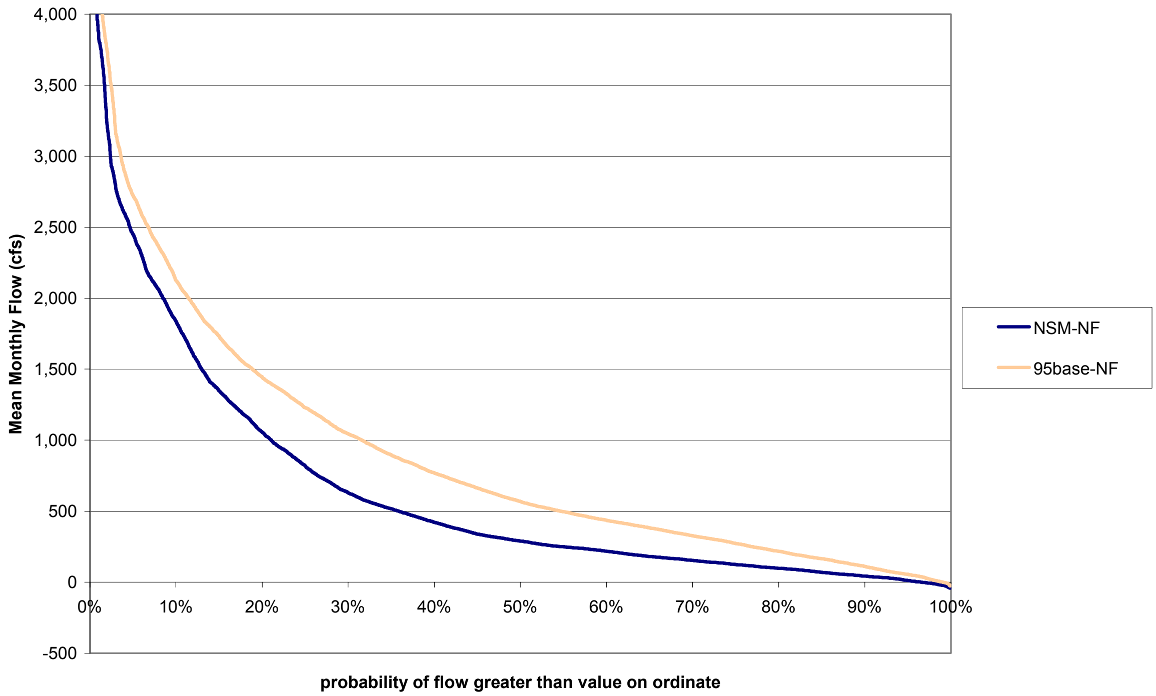

Figure 15. Frequency Distribution of Flows to the St. Lucie Estuary for NSM and 1995 Base Case Model Simulations

EFFECTS ON THE SOUTH FORK OF THE ESTUARY

Examination of the flow distribution for the South Fork of the St. Lucie Estuary (**Figure 16**) indicates a similar, but less dramatic trend. Overall flows to this river have decreased about 22 percent (**Table 11**). The simulated flow data indicate that more flow is occurring to the river during dry periods. Examination of the frequency distribution curve (**Figure 17**) indicates that the overall decline in flows to the South Fork of the estuary of 22 percent (**Table 11**) has occurred primarily due to a decrease in high flow events.

The two curves shown in **Figure 17** cross each other at about 100 cfs. This shows that the probability of mean monthly flow rates above 100 cfs has declined under the 1995 Base Case conditions, whereas the probability of flows below 100 cfs has increased slightly.

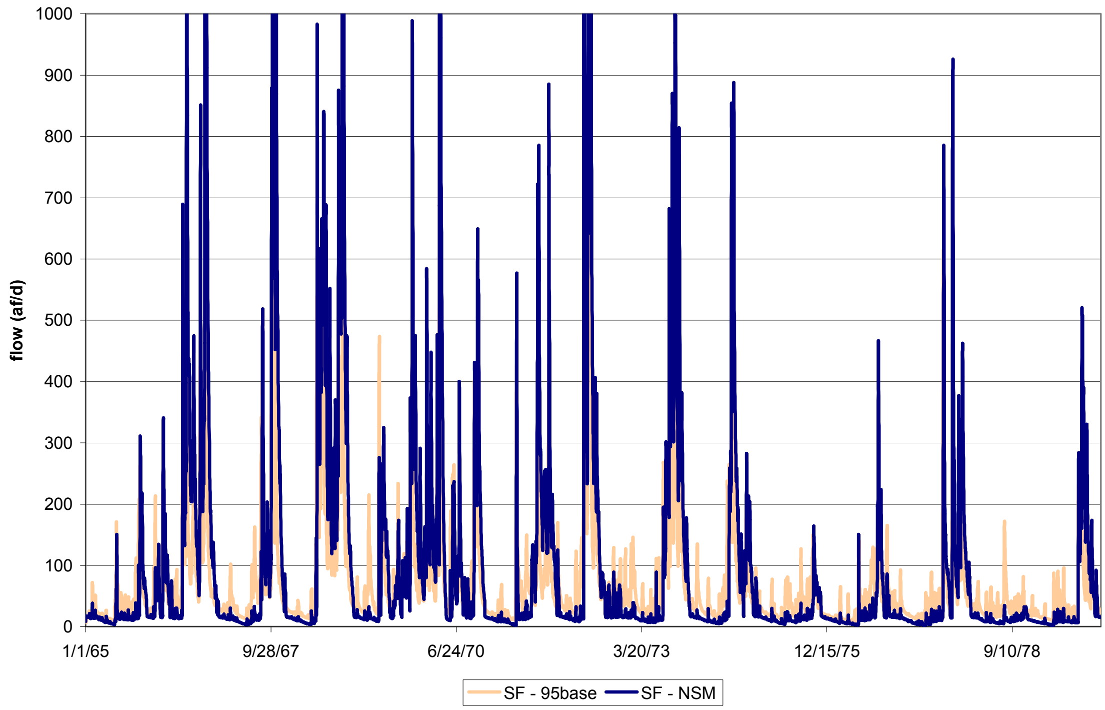

Figure 16. NSM and 1995 Base Case Flows to the South Fork of the St. Lucie Estuary for the 31-Year Period from 1965-1995

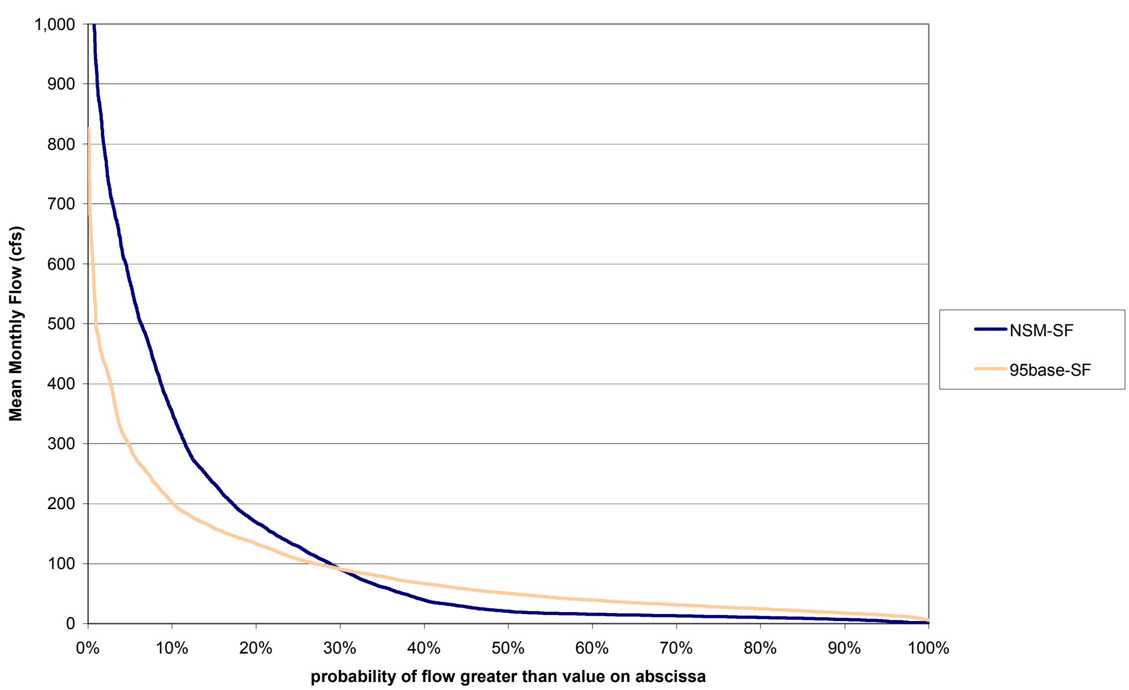

Figure 17. Frequency Distribution of Flows to the South Fork of the St. Lucie Estuary for NSM and 1995 Base Case Model Simulations

EFFECTS ON THE NORTH FORK OF THE ESTUARY

Figures 18 and **19** show the historic and current pattern of flows to the North Fork of the St. Lucie Estuary. As with the South Fork, the overall decline in flows of 39 percent has occurred due to a reduction in high flow events.

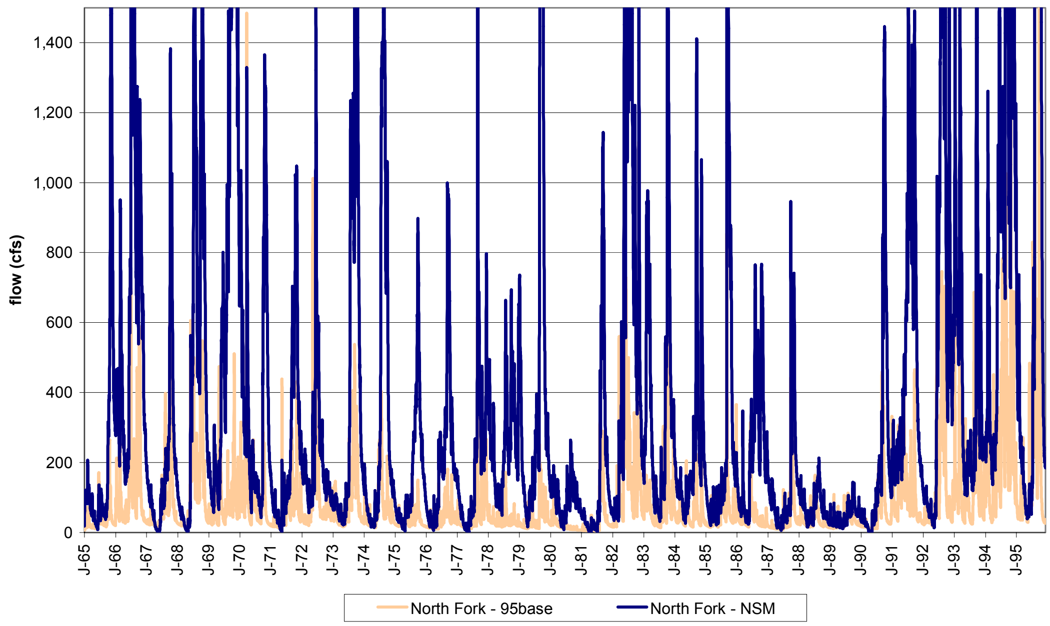

Figure 18. NSM and 1995 Base Case Flows to the North Fork of the St. Lucie Estuary

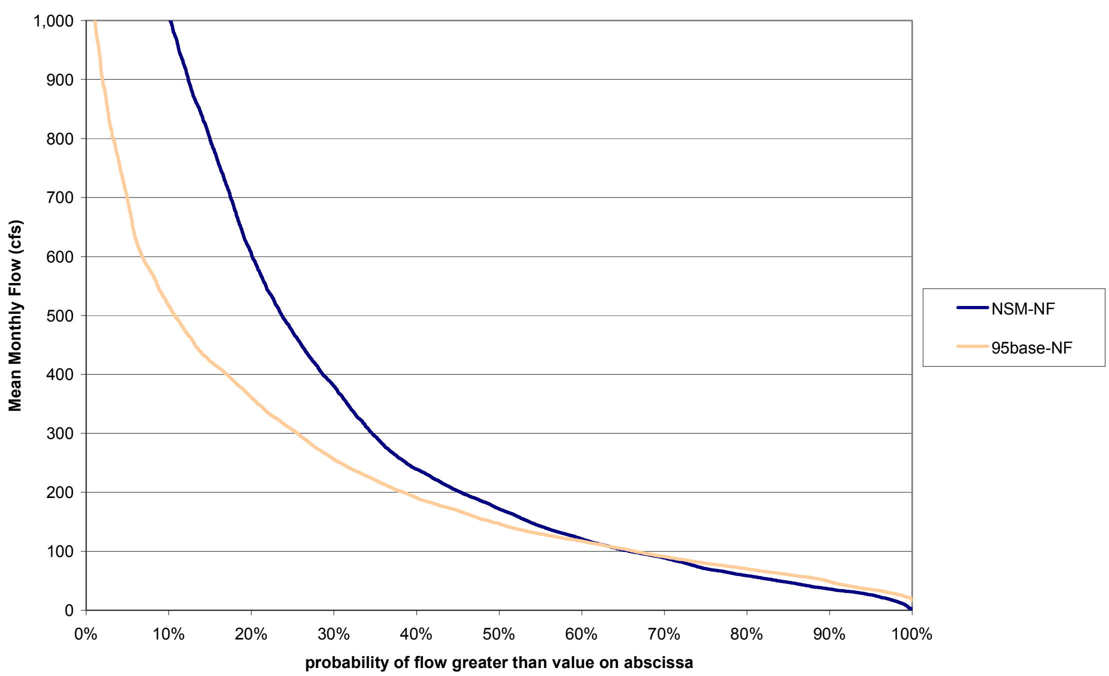

Figure 19. Frequency Distribution of Flows to the North Fork of the St. Lucie Estuary

Peak discharges were of similar maximum rate. However, under NSM conditions, high discharge events typically persisted for longer periods of time. Total volume of discharge (as represented by the area under the curve) was greater for NSM conditions than for 1995 Base Case conditions. Periods of low freshwater release were of similar frequency and duration, but under the 1995 Base Case, more frequent pulses of fresh water were released due to local rainfall events. This resulted in greater variability of flow conditions that could lead to more rapid changes in salinity in the estuary.

The two curves shown in **Figure 19** cross each other at about 100 cfs. This shows that the probability of mean monthly flow rates above 100 cfs has declined under the 1995 Base Case conditions, whereas the probability of flows below 100 cfs has increased slightly.

EFFECTS ON THE CENTRAL ESTUARY

As indicated in **Table 11**, flows to the center of the estuary through the major canals have increased by a factor of ten or more. This area of the estuary has been highly impacted by shoreline development and dredging and filling, resulting in loss or degradation of most of the remaining plant and animal communities. Establishment of minimum flow regimes is much less a concern than habitat restoration efforts and establishing maximum discharge criteria for these areas of the system. The limited shoreline and poor quality bottom sediments provide lower quality and less stable oligohaline habitat.

ANALYSIS OF FLOWS DURING DROUGHT CONDITIONS

Representative flow conditions that occur during a deficit rainfall period were selected using total flows to the estuary as predicted by the NSM simulation. The deficit flow period was defined as a three-month period or longer of unusually low flows. The 31-year period of record was examined and the period of below normal flows was selected from the final months of a dry (1-in-5 to 1-in-10 return period) dry season. **Figure 20** shows the selected dry period for both 1995 Base Case and predevelopment conditions.

Note that base flows for both are similar during the selected period, but 1995 Base Case conditions has a "flashier" response to rainfall events, as compared to NSM conditions. Similar low-flow conditions in the range observed during the selected minimum flow period occur during most years, but generally do not persist for an extended period of time.

Table 12 shows the total monthly flow entering the estuary under NSM conditions for each month of the 31-year period of simulation. The five potential dry seasons (1973, 1976, 1977, 1987, and 1989) are shaded. The representative low flow period, as shown in the boxed cells in **Table 12**, extended from March 1 to May 31, 1987. During this period, average monthly flows declined from 96 cfs to -9 cfs. This pattern of decline is typical for the dry season in this estuary. The magnitude of decline is representative of approximately a 1-in-10 year drought condition.

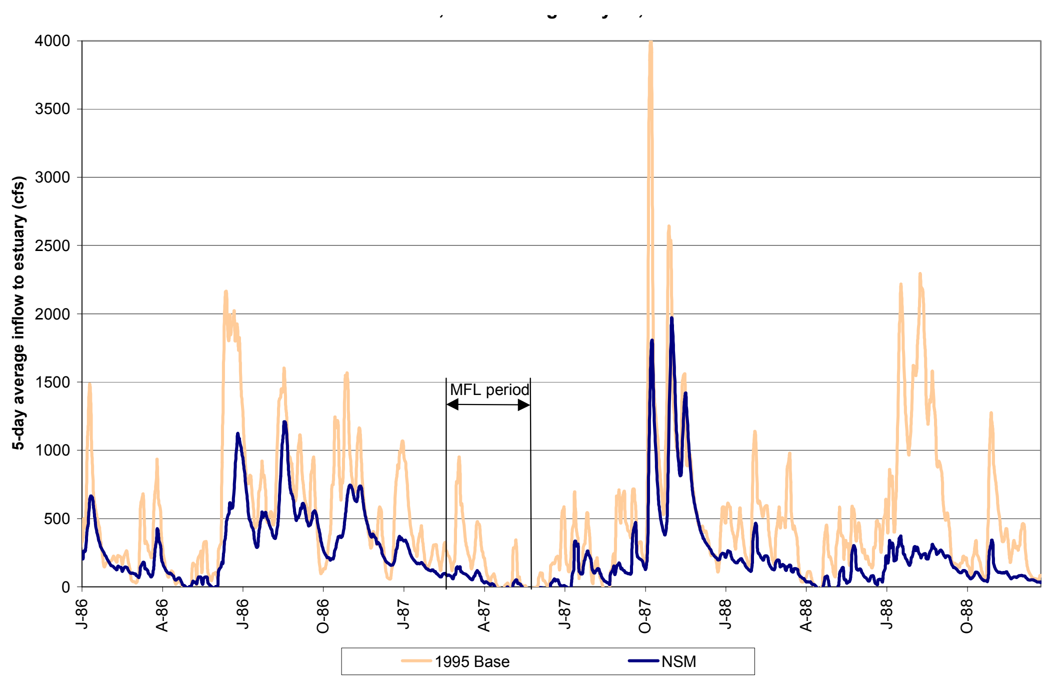

Figure 20. Selected Low Flow Period for 1995 Base Case NSM Conditions (March 1, 1987, thorough May 31, 1997)

DEFINITIONS OF HARM AND SIGNIFICANT HARM

Flows at or below zero (light gray-shaded numbers in **Table 12**) occurred 14 times during the 31-year simulation period. Periods of low or even negative flow (negative flow occurs when the rate of evaporation from the estuary surface exceeds the rate of freshwater inflow from tributaries) may persist for one to nine months. During such periods, it can be expected that the oligohaline habitat will no longer be present.

Harm is defined to occur to this estuary system when freshwater flows are less than the rate of evaporation for a period of two consecutive months during the dry season. Under these conditions, it is expected that most of the oligohaline zone will be lost or impacted.

Such conditions occurred five times during the period of simulation, representing a return frequency of about 6 years under natural system conditions. These five two-month periods occurred during the NSM simulation for 1965 to 1995 rainfall conditions. These events (indicated by light gray shading in **Table 12**) occurred during April and May of 1967, 1977, 1981, and 1990, and during May and June of 1987. Because such low flow and no flow events occurred under natural conditions as well as under present conditions, the extent to which such occurrences constitute "significant harm" to the ecosystem is based on the definition that has been formally adopted by the SFWMD:

<u>Significant Harm</u> occurs when freshwater flows to the estuary are less than the rate of evaporation for a period of two consecutive months during the dry season for two or more years in succession.

Such an event did not occur during the 31-year period of simulation for the St. Lucie Estuary under NSM conditions.

Table 12. Monthly Flows[a] to the St. Lucie Estuary for NSM Conditions[b]

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1965	260	247	133	58	2	215	168	128	168	791	1,504	469
1966	608	652	751	303	264	1,273	2,284	1,812	1,405	2,349	915	387
1967	202	165	103	-1	-24	130	202	638	527	2,797	832	287
1968	136	90	27	-20	131	1,469	2,444	1,337	1,293	2,857	1,297	394
1969	245	132	288	148	696	891	533	1,200	1,677	3,590	3,128	1,462
1970	1,175	833	1,695	939	207	458	444	229	243	1,641	1,054	302
1971	140	108	45	2	353	170	274	388	1,246	1,108	1,185	464
1972	239	249	141	181	1,243	2,712	971	423	288	242	259	180
1973	175	179	73	45	68	213	665	1,855	2,738	2,039	792	287
1974	220	89	60	20	54	250	1,401	1,943	1,276	878	316	206
1975	100	79	42	-5	155	105	187	330	598	842	350	180
1976	82	50	19	32	39	364	274	430	1,144	689	395	260
1977	219	96	26	-22	-1	84	164	321	1,626	814	595	1,010
1978	569	328	273	99	139	104	293	458	294	546	465	282
1979	578	203	86	34	178	193	226	288	3,234	2,405	587	347
1980	186	245	154	120	23	-20	37	49	164	86	51	46
1981	35	51	0	-40	-3	1	32	585	1,352	596	263	107
1982	79	118	264	492	1,179	3,001	2,388	2,549	1,319	1,041	2,085	657
1983	419	721	931	428	102	99	23	266	383	1,984	1,346	544
1984	428	189	230	141	108	137	157	216	763	774	618	531
1985	199	71	108	195	116	99	222	238	2,019	1,554	619	292
1986	373	136	164	87	32	458	568	690	515	318	596	255
1987[c]	226	97	96	8	-9	-1	101	114	186	666	1,172	349
1988	208	226	144	27	54	98	223	238	207	83	133	61
1989	36	13	151	126	65	40	167	210	147	261	144	101
1990	54	61	34	-14	-22	40	120	374	647	1,903	802	252
1991	298	319	312	577	520	830	1,246	1,337	1,080	1,476	530	305
1992	202	180	112	91	14	745	1,857	3,679	2,897	1,969	1,956	925
1993	1,502	1,386	1,632	1,310	305	293	302	243	925	2,645	739	480
1994	425	1,064	715	454	494	1,136	1,872	2,609	3,500	2,555	3,699	3,116
1995	1,473	698	414	495	218	378	536	3,853	4,247	7,134	1,781	371
Number of events less than 0 cfs			1	6	5	2						

a. Monthly flows are determined from average daily cfs

b. Drier dry seasons are shaded dark gray and total flows to the estuary less than zero are shaded light gray.

c. Period from March to May outline with double lines is the selected representative low flow period

A similar analysis was conducted for 1995 Base Case conditions and the results are shown in **Table 13**. As with the NSM simulation, the estuary experienced occasional periods of zero or negative flow. However, these periods of reduced flow occurred less often, were less severe (lower volume of deficit), and were of shorter duration than the periods of low flow that were simulated under natural systems conditions. In fact, during the 31 years of simulation, only two months (May 1965 and April 1981) had flows that

Table 13. Monthly Flows[a] to the St. Lucie Estuary for 1995 Base Case Conditions[b]

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1965	91	318	87	35	-13	403	704	395	784	1,923	1,471	356
1966	1,230	1,154	702	365	904	2,269	1,986	1,874	1,654	3,512	748	484
1967	313	505	243	15	8	549	966	1,373	765	2,525	493	310
1968	196	240	115	4	344	2,346	2,687	1,520	2,030	3,785	1,352	318
1969	534	362	1,352	274	2,109	893	542	1,369	2,023	3,797	2,497	1,463
1970	1,377	1,176	3,741	1,042	474	1,680	1,178	1,007	1,096	2,673	807	172
1971	209	346	124	37	306	444	651	866	1,032	1,303	1,550	561
1972	380	476	251	657	1,326	2,661	1,166	663	360	408	492	423
1973	515	559	230	186	243	844	1,746	1,504	2,485	2,355	597	241
1974	312	113	65	196	160	965	2,575	2,610	1,006	840	452	454
1975	131	202	109	20	457	415	1,069	859	1,094	671	224	125
1976	49	112	55	54	534	1,018	430	739	1,453	364	478	418
1977	294	180	79	12	104	237	372	478	1,841	829	763	939
1978	595	411	454	168	383	396	727	643	598	735	724	588
1979	1,480	337	197	129	733	535	713	678	4,721	1,897	633	548
1980	444	664	373	418	242	115	267	307	461	144	132	79
1981	46	138	3	-24	72	38	198	1,368	1,869	464	178	57
1982	114	312	1,069	1,674	1,360	2,456	2,284	2,760	1,264	1,284	2,128	640
1983	786	2,543	1,713	615	106	574	408	1,101	1,817	2,786	1,103	843
1984	699	340	697	302	321	661	1,296	863	2,196	909	1,325	645
1985	195	78	266	485	110	196	750	867	2,499	826	493	319
1986	569	188	389	101	138	1,336	811	947	689	708	741	418
1987	488	226	411	88	56	86	320	134	500	1,249	1,357	359
1988	443	542	483	75	308	320	948	1,557	550	171	566	208
1989	135	37	210	244	141	166	422	811	433	607	221	270
1990	206	171	70	26	89	259	429	851	1,604	1,862	485	122
1991	798	540	591	1,047	765	1,644	1,657	1,427	1,481	2,015	453	334
1992	155	411	224	215	28	1,708	1,692	4,158	3,038	1,762	1,554	699
1993	2,581	1,583	2,545	1,062	274	906	1,195	556	1,325	3,080	1,118	764
1994	1,115	2,029	770	921	896	2,000	1,697	2,055	3,981	2,280	3,884	3,753
1995	1,375	683	750	513	336	886	1,296	5,461	3,438	8,134	1,111	418
Number of events less than or equal to 0 cfs				1	1							

a. Average daily cfs

b. Drier dry seasons are shaded dark gray and total flows to the estuary less than zero are shaded light gray.

were zero or below. Since these two events did not occur in consecutive months, the estuary (as a whole) did not incur harm, due to deficient freshwater flows, during this simulation.

ADDITIONAL EXAMINATION OF THE NORTH AND SOUTH FORKS OF THE ST. LUCIE RIVER

Even though the estuary as a whole may not be impacted by lack of freshwater inflow, particular areas within this system may be experiencing stress or damage during dry periods. For this reason, the District developed a more detailed analysis for the North and South Forks of the St. Lucie River. Both of these areas support fish, wildlife, and plant communities that are dependent on an influx of fresh water and have substantial, persistent oligohaline zones. For this analysis, data developed for the Indian River Feasibility Study (USACE and SFWMD, 2001) were heavily utilized. Prior District research efforts and development of the feasibility study options have focused primarily on analysis of the North Fork. Specific models have been developed to address hydrologic conditions in this river system. By contrast, much less is known about and much less effort has been spent to analyze conditions in the South Fork. Conclusions derived for the South Fork are based on results obtained from the large-scale regional models and by extrapolation from the analysis of the North Fork. More detailed study of the South Fork and its watershed is warranted before specific criteria are recommended for this system.

North Fork of the St. Lucie River

As shown in **Table 11**, overall discharges to the North Fork of the St. Lucie River have decreased by about 40 percent. This reduction in overall flow has occurred primarily due to a reduced frequency of high flow events, as floodwaters have been diverted into the C-24 Canal. Results of the analyses of salinity conditions and flow in the North Fork River indicate that there is a direct linkage between hydrologic conditions within the system and resulting salinity conditions in the estuary. By restoring historic hydrologic flow patterns to the river, the District should be able to restore some semblance of historic salinity regimes in the estuary (Estevez, 2000). Salinity conditions, in conjunction with suitable substrate and overall water quality, in turn will determine the ecosystems that can be expected to occur.

Therefore, restoration of proper salinity conditions may contribute to overall restoration of plant and animal communities. In order to document or monitor such beneficial changes in the St. Lucie Estuary, it may be necessary to artificially establish submerged aquatic vegetation or oysters to overcome historic recruitment bottlenecks, and then study their responses to managed flows and salinities. Flows could be varied experimentally, or managed flow regimes could be monitored through time so as to allow periodic assessments of progress and adjustments to flow (Estevez, 2000). Analysis of predicted historic hydrologic conditions and careful documentation of the effects of future modified hydrologic conditions, using an adaptive management approach, can thus provide a means to achieve ecosystem restoration.

Extent of Oligohaline Habitat

A GIS analysis was conducted to analyze the features of the North Fork and identify reaches of the river that would be most likely to benefit from maintenance of oligohaline conditions. The river was accurately mapped to include both shorelines (**Figure 21**) and the data were analyzed to estimate the surface area (in acres) of available substrate for colonization by benthic communities. Representative data from this analysis, at approximately 1-mile intervals, are shown in **Table 14**.

Table 14. Representative Data from the GIS Analysis of the North Fork of the St. Lucie River

Segment	Segment Length	Segment Acres	Total Length	Total Acres	Miles
N006	915.313	1.79	5865.457	11.64	1.110882
N011	1036.568	2.01	11002.058	21.62	2.083723
N015	1042.915	2.02	15206.850	29.81	2.880085
N021	1161.402	2.25	21963.793	67.52	4.159809
N025	1215.656	2.37	26753.059	76.85	5.066867
N030	1024.613	2.00	32506.883	88.05	6.156607
N034	1060.989	2.07	36595.656	96.02	6.930995
N038	1477.508	5.10	41986.527	112.33	7.951994
N045	788.386	10.79	49751.190	184.71	9.422574
N046	4063.274	28.31	53814.464	213.02	10.19213
N048	2072.925	9.62	57717.599	237.90	10.93136
N051	1414.794	8.09	63558.373	269.93	12.03757
N055	1941.493	20.45	69835.790	311.69	13.22648
N058	1825.690	17.79	74446.975	348.63	14.09981
N062	1087.820	14.64	79382.860	392.44	15.03463
N067	1040.239	7.22	84760.102	432.70	16.05305
N073	462.663	62.31	90528.403	529.12	17.14553
N080	1401.406	16.19	98010.605	635.40	18.29720
N083	1075.879	69.37	101316.637	941.67	19.18876
N087	1061.443	97.55	105649.157	1295.89	20.00931
N092	1019.125	90.88	110603.605	1743.00	20.94765
N099	1070.941	87.76	117784.337	2357.89	22.30764
N105	930.414	62.67	124908.254	2881.84	23.65687

Figure 21 indicates that a significant change in the nature of the river channel occurs at a distance of approximately 8 miles. This corresponds to a widening and dividing of the main channel and the adjacent floodplain. As shown in **Table 14**, during the first 7.9 miles, habitat increases gradually to cover 112 acres - an average rate of about 14 acres per mile. From 8 to 10 miles, this rate increases approximately three-fold. Total area approximately doubles over this two-mile interval from 112 acres at 7.9 miles to 213 acres at 10.2 miles. This corresponds to a rate of increase of benthic habitat of about 44 acres per mile.

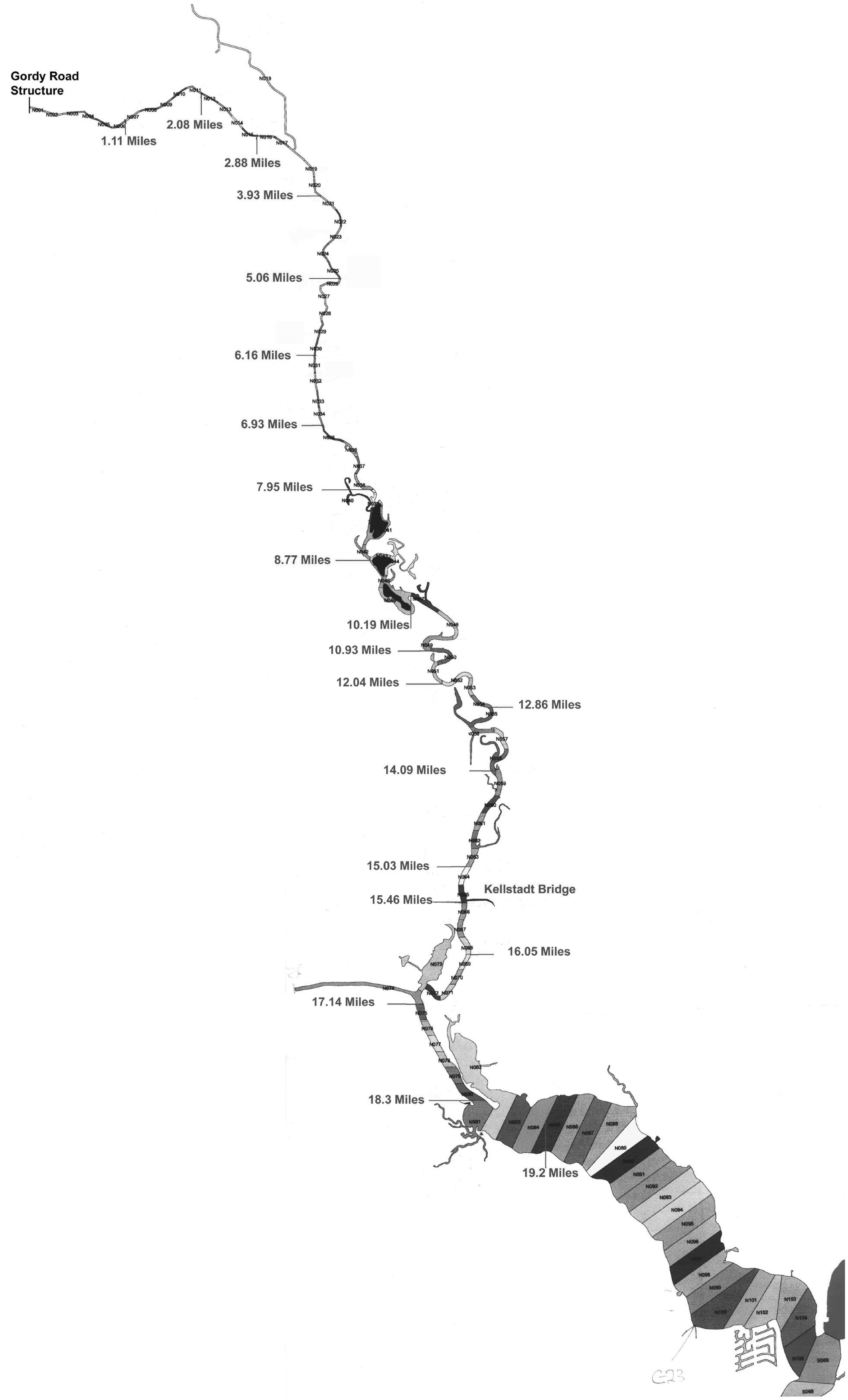

Figure 21. Results of the GIS Analysis of the North Fork of the St. Lucie River, Showing Major Features of the River and Mileage Downstream from the Gordy Road Structure

The depth data were then incorporated to calculate the volume of oligohaline habitat that could be utilized by pelagic and planktonic species. Results of this analysis (**Figure 22**) show how the total volume of oligohaline habitat increases as a function of distance downstream. Total habitat volume in the North Fork River increases at an average rate of about 50 acre-feet per mile for the first 8 miles. Habitat volume more than doubles from approximately 400 acre-feet at 8 miles to more than 1,000 acre-feet at 10 miles - a rate of about 300 acre-feet per mile. This transition point where potential oligohaline habitat begins to increase rapidly as a function of distance is considered to be a critical feature of the North Fork system that provides a basis for assessing potential impacts of freshwater deliveries.

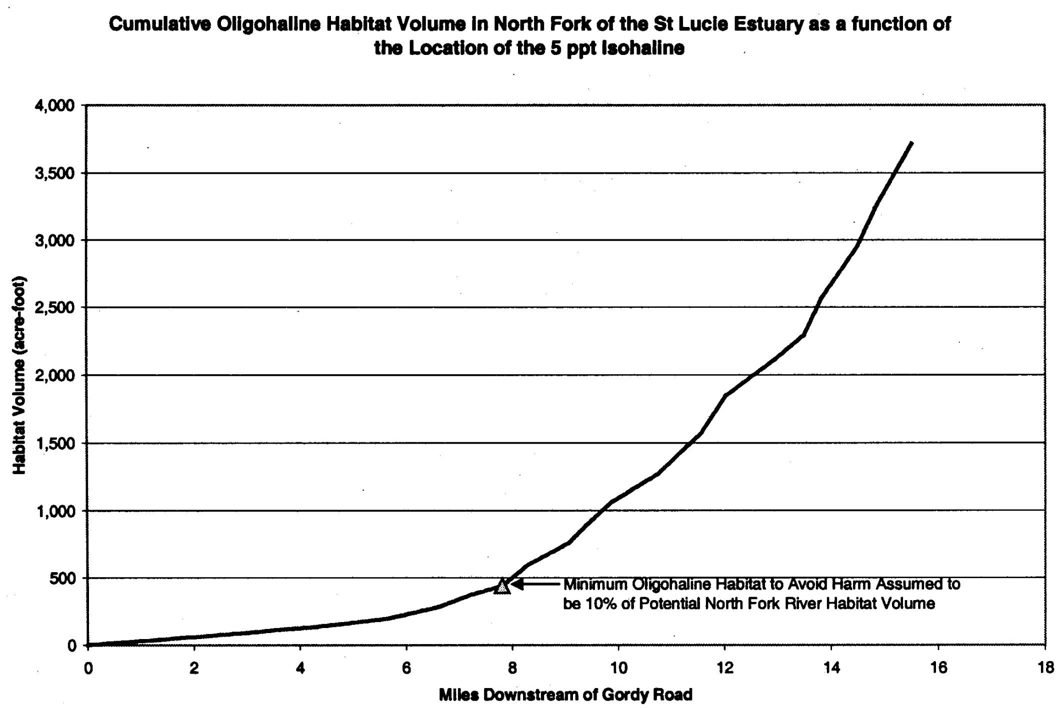

Figure 22. Total Volume of Oligohaline Zone Habitat in the North Fork of the St. Lucie River as a Function of Distance Downstream from Gordy Road

Flows Needed to Maintain Oligohaline Habitat in the North Fork

A hydrodynamic model was developed for the St. Lucie Estuary to predict salinity conditions based on tidal exchange, river flow, and basin configuration (Hu, 2000). This model was modified and extended to include the North Fork, from Kellstadt Bridge to the Gordy Road structure, a distance of about 15 miles (**Appendix F**). The model was used to develop a relationship between freshwater inflow and salinity at various distances along the river (**Figure 23**). Inflow was from Ten Mile Creek, Five Mile Creek, rainfall, and ground water seepage.

Results of this analysis indicate how much flow is needed in order to maintain a 5-parts per thousand (ppt) oligohaline zone at different locations within the river. For example, to maintain the oligohaline zone at a point 7 miles above the Kellstadt Bridge

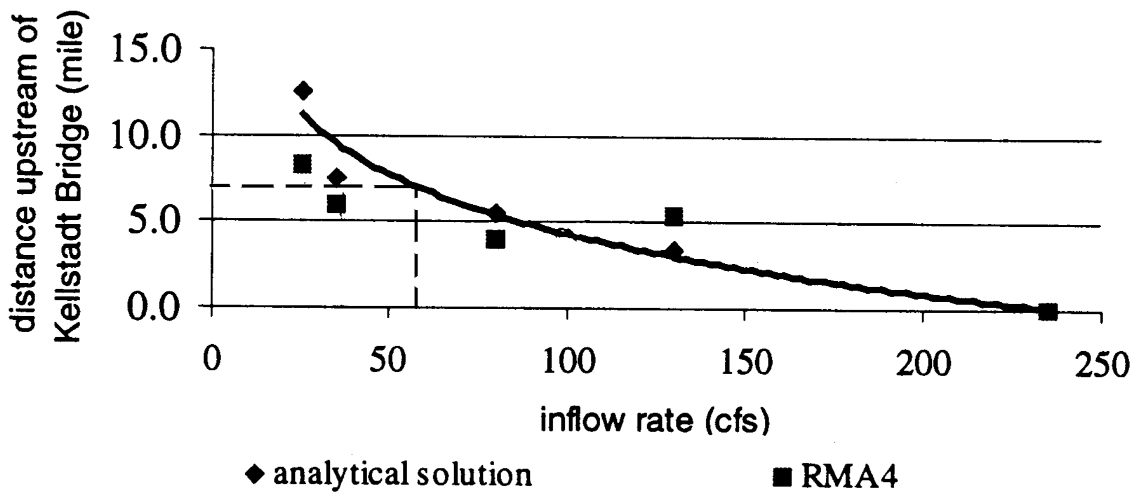

Figure 23. Location of the 5 ppt Isohaline Zone as a Function of Discharge from the Gordy Road Structure Based on the 1995 Base Case

(which corresponds to 8 miles downstream from the Gordy Road structure), a flow of about 70 cfs is required (**Figure 23**). Likewise, to maintain the 5-ppt isohaline zone at or below the Kellstadt Bridge would require an estimated flow of 240 cfs or more. These flows were developed from mathematical models of the estuary, which in turn, were based on limited sets of measured flow and salinity data, and do not represent actual measured values. Due to limitations of the models, very low flows (less than 25 cfs) are not estimated accurately and need to be interpreted with caution.

Output from the NSM for the North Fork was further analyzed to determine the frequency and duration of events when flows declined below 70 cfs, resulting in loss of the more extensive areas of potential oligohaline habitat. Results of this analysis are shown in **Table 15**. Simulated flows ranged from a minimum of 3 cfs to a maximum of 3,879 cfs. Flows were at or below 70 cfs during 93 of the 372 months of the simulation, or about 25 percent of the time under NSM conditions.

During those periods when the NSM predicted that total flows to the estuary were zero or less (**Table 15**), flows from the North Fork were generally at or below 21 cfs. For example, during April and May of 1967, 1977, 1981, and 1990, the NSM predicted flows in the North Fork that ranged from 3 cfs (June 1965) to 21 cfs. An exception occurred during May 1987 when total flows to the estuary were -9 cfs while flows from the North Fork were 29 cfs. Of the total number of 13 months when average flows were below 21 cfs, 10 of these were associated with periods when total flows to the estuary were less than zero.

A similar analysis was conducted using the 1995 Base Case conditions. Results of this analysis are shown in **Table 16**. Flows to the North Fork ranged from 20 cfs to 1,863 cfs, representing both an increase in the amount of base flow and a dramatic decrease in maximum flows. The number of months when flows were below 70 cfs declined to 80, which represents about 21 percent of the period of simulation. Flows of 21 cfs or below only occurred twice, during April 1968 and April 1981. April 1981 was also a month when total flows to the estuary under 1995 Base Case conditions (**Table 13**) were less than zero. During May 1965, total flows to the estuary under 1995 Base Case conditions were -13 cfs (**Table 13**), while flows from the North Fork were 22 cfs (**Table 16**).

Table 15. Monthly Flows[a] to North Fork as Predicted by Natural Systems Model Conditions[b]

Year	Month											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
1965	98	112	69	51	23	62	70	54	72	414	1,270	403
1966	407	422	508	211	183	569	1,408	1,331	828	993	634	277
1967	147	98	63	21	3	47	93	168	236	926	350	169
1968	91	54	31	8	30	367	1,416	831	651	1,407	791	272
1969	168	90	185	119	208	631	436	989	1,440	###	2,453	1,212
1970	751	438	446	414	134	181	140	101	90	894	880	260
1971	120	70	42	25	51	69	107	158	501	703	634	273
1972	169	193	103	103	167	717	480	236	175	126	132	91
1973	82	92	52	41	42	98	345	1,088	1,426	1,325	559	195
1974	134	69	34	26	40	82	472	1,412	1,079	586	175	121
1975	69	45	34	17	59	67	96	254	449	587	253	146
1976	68	32	25	33	51	229	189	264	719	538	264	168
1977	136	71	40	13	19	49	67	235	946	329	242	459
1978	388	247	224	92	102	95	258	391	241	454	356	234
1979	564	211	94	36	94	138	210	267	###	1,969	391	241
1980	128	130	97	107	36	26	81	93	203	122	98	73
1981	48	45	22	4	17	18	25	217	847	416	177	80
1982	50	60	82	298	530	1,291	1,347	1,789	969	665	784	299
1983	207	558	774	323	103	100	49	126	215	1,248	847	327
1984	237	123	127	81	62	83	144	167	539	569	385	373
1985	141	62	47	61	49	58	95	119	1,260	1,238	534	188
1986	156	77	95	75	39	156	259	474	445	293	568	204
1987	191	96	106	51	29	18	34	50	64	325	536	213
1988	128	106	82	35	36	39	72	118	159	72	60	40
1989	35	24	39	31	28	21	33	60	56	90	67	60
1990	43	38	25	9	6	36	79	170	226	1,089	600	191
1991	145	195	210	263	247	432	908	1,038	870	1,020	405	203
1992	135	102	74	58	26	135	724	1,719	1,585	1,032	737	514
1993	800	816	855	793	185	148	219	169	226	1,144	393	300
1994	239	602	445	201	240	698	1,183	1,005	1,567	1,542	1,590	1,798
1995	965	487	250	160	73	69	96	1,126	2,756	3,879	1,344	268
Number of events less than or equal to 70 cfs (Total = 93)	**6**	**10**	**13**	**17**	**19**	**13**	**6**	**3**	**2**	**0**	**2**	**2**
Number of events less than or equal to 21 cfs (Total = 13)				**6**	**4**	**3**						

a. Average daily cfs

b. Periods when net freshwater flow to the estuary was less than zero are shaded dark gray.

Table 16. Monthly Flows[a] to North Fork as Predicted by 1995 Base Case Conditions[b]

Year	Month											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
1965	28	149	44	35	22	104	230	108	252	668	627	125
1966	393	365	202	122	293	619	596	409	239	575	160	109
1967	81	122	62	32	24	181	224	262	161	276	65	76
1968	73	58	35	20	57	409	405	185	285	517	185	64
1969	93	58	269	52	434	198	140	407	698	1,058	628	378
1970	205	189	393	129	119	116	134	115	205	659	255	59
1971	44	87	35	39	56	194	144	320	171	348	238	155
1972	103	218	100	205	188	571	223	162	62	110	97	73
1973	104	84	62	57	114	204	607	511	616	484	109	68
1974	64	31	26	88	52	230	704	687	191	108	52	80
1975	36	104	49	32	153	75	276	327	460	210	105	60
1976	33	51	36	35	276	322	132	304	576	107	133	120
1977	92	56	36	35	79	109	178	247	686	281	267	300
1978	237	137	172	75	233	184	355	294	329	342	270	247
1979	377	73	61	73	342	187	395	318	1,863	592	127	146
1980	120	177	149	202	90	83	145	152	272	89	90	59
1981	32	85	25	21	72	37	159	502	739	176	60	29
1982	59	115	346	782	519	796	851	1,000	357	269	195	93
1983	190	571	343	106	72	101	125	198	349	411	153	141
1984	79	115	135	62	130	208	375	181	766	269	366	139
1985	68	33	110	168	62	80	200	281	805	251	167	86
1986	105	40	114	30	65	426	181	118	143	268	298	131
1987	116	68	178	40	64	36	105	65	206	362	393	89
1988	108	98	134	55	100	80	244	282	135	54	93	67
1989	62	29	60	70	75	76	103	240	121	163	106	146
1990	67	70	34	43	92	140	206	274	462	618	183	62
1991	161	117	176	242	246	675	581	495	461	439	92	93
1992	69	143	58	81	26	335	341	1,041	429	243	376	140
1993	378	205	489	151	48	221	429	148	187	752	189	134
1994	176	614	182	132	136	433	456	401	767	341	389	782
1995	218	139	116	64	38	103	113	879	471	1,381	164	56
Number of events less than 70 cfs (Total = 80)	**11**	**10**	**14**	**17**	**11**	**2**	**0**	**1**	**1**	**1**	**3**	**9**
Number of events less than or equal to 21 cfs (Total = 2)				**2**								

a. Average daily cfs

b. Periods when net freshwater flow to the estuary was less than zero are shaded dark gray.

Summary

Results of these analyses indicate that for the 1995 Base Case overall flows to the North Fork have declined compared to NSM conditions and discharges during dry periods have increased. Results of the GIS analysis indicate that available habitat increases slowly with distance down the river and then begins to increase rapidly when the river channel widens at a point about 8 miles downstream from the Gordy Road structure. Analysis of flow-salinity relationships indicates that a flow of about 70 cfs (about 4,000 acre-feet per month) is needed to maintain the oligohaline zone more than 8 miles downstream. Flows below this rate will result in the loss of the most extensive areas of potential oligohaline habitat.

Analyses of flow data for NSM and 1995 Base Case conditions indicate that flow rates in the North Fork fall below 70 cfs on a recurring basis. Under NSM conditions, flows of more than 70 cfs (4,000 acre-feet per month) can be expected to occur 75 percent of the time. Under 1995 Base Case conditions, this rate of flow or more can be expected to occur more often, approximately 80 percent of the time. Flow rates of 21 cfs or below in the North Fork generally occur during periods when the St. Lucie Estuary is experiencing zero or negative net inflow of fresh water. The incidence of very low flows (21 cfs or below) declines from 13 months under NSM conditions to two months under the 1995 Base Case conditions.

Relationship to Significant Harm

Within the North Fork of the St. Lucie River, the conditions that cause significant harm to oligohaline habitat do not occur. Thus, even under the driest conditions when oligohaline habitat does not exist in the main part of the estuary, some oligohaline habitat is likely to persist in the upper reaches of the North Fork. Based on model simulations, the extent of this persistent oligohaline habitat appears to be greater under present (1995 Base Case) discharge regimes than it was under NSM conditions. When monthly average discharges rates from the North Fork River, as predicted by the models, are 21 cfs or less, oligohaline habitat no longer exists in the estuary.

South Fork of the St. Lucie River

A similar analysis of present and NSM conditions was conducted for the South Fork of the St. Lucie River. However, less information was available for this system in terms of historical flow measurements and salinity and a GIS analysis of this portion of the river has not been undertaken. No model is currently available to predict salinity conditions in the South Fork as a function of flow. The analysis was based strictly on the application of large-scale regional and subregional models.

Discharge characteristics of the South Fork were estimated by District staff based on consideration of the relative sizes of the watersheds, the average amount of runoff predicted by NSM, and the shapes of the discharge hydrographs. The North Fork has a watershed of approximately 106,000 acres and an average amount of runoff (predicted by

NSM) of 1,475 cfs. The South Fork has a watershed of 49,000 acres, which is 46 percent of the size of the watershed of the North Fork. Runoff as predicted by NSM is 446 cfs, or about 30 percent of the amount that flows into the North Fork. No detailed hydrographic data are available for the South Fork. District staff estimated that a flow of 27 cfs (38 percent of the North Fork target) may provide oligohaline conditions in the South Fork that would be comparable to the habitat provided by a flow of 70 cfs in the North Fork. This number is shown in the table as a suggested management target for the South Fork system.

NSM and 1995 Base Case Model Results

For NSM conditions (**Table 17**), flows in the South Fork River ranged from a minimum value of 1 cfs to a maximum of 1,220 cfs. Flows were below the 27 cfs management target during 206 of the 372 months of simulation, which represents about 55 percent of the total simulation period. During periods when total freshwater flow to the estuary (**Table 12**) was zero or less - April and May of 1967, 1977, 1981, and 1990, and May and June of 1987 - the NSM predicted flows in the South Fork that ranged from 1 cfs (April 1981 and June 1987) to 7 cfs (April 1967). Flows to South Fork were 7 cfs or less during 45 months or 12 percent of the simulation period.

For the 1995 Base Case (**Table 18**), flows ranged from a minimum of 6 cfs to a maximum flow of 795 cfs. Flows less than 27 cfs occurred during 95 months, which represents 24 percent of the simulation period. Flows of 7 cfs or less occurred twice under the 1995 Base Case simulation. The South Fork River thus currently receives more water during dry periods and less water during high discharge events than occurred under NSM conditions.

Relationship of NSM and 1995 Base Case Flows to Significant Harm Criteria

No evidence was found of the South Fork system experiencing significant harm due to a complete loss of oligohaline habitat (zero flow) under historic conditions. The South Fork is also much less likely to experience such an impact under current conditions. During periods when zero net flow of fresh water was occurring to the St. Lucie Estuary, the South Fork had a flow rate of 7 cfs or less. Such flows occurred about 12 percent of the simulation period under NSM conditions, but less than 1 percent of the time (during 2 of 372 months) under current (1995 Base Case) conditions.

Table 17. Monthly Flows[a] to South Fork as Predicted by Natural Systems Model Conditions[b]

Year	Month											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
1965	16	17	13	9	6	22	15	14	15	87	81	16
1966	53	84	94	29	17	240	460	231	268	676	141	32
1967	15	14	12	7	5	10	14	158	110	884	280	39
1968	14	12	9	5	15	421	515	254	308	704	285	47
1969	16	13	16	11	158	125	24	74	69	232	332	113
1970	191	191	504	330	17	110	142	40	31	356	90	14
1971	11	11	9	5	85	15	21	85	382	180	267	81
1972	18	15	12	13	443	931	272	87	33	32	33	18
1973	17	23	12	9	9	16	87	342	606	335	111	21
1974	16	12	10	7	7	17	381	279	84	151	49	23
1975	14	12	9	6	13	9	14	13	18	80	32	14
1976	10	9	7	7	4	19	14	22	152	67	33	17
1977	16	12	8	5	4	8	13	13	213	198	148	236
1978	78	17	15	10	10	7	9	11	11	13	24	12
1979	9	6	5	5	12	11	9	8	247	212	81	30
1980	15	22	15	11	6	3	2	1	1	1	1	1
1981	2	3	2	1	2	2	5	91	166	62	20	13
1982	11	11	26	62	275	761	487	328	168	198	588	166
1983	71	36	39	44	10	8	5	23	25	200	259	76
1984	96	16	24	15	12	12	9	11	30	41	81	65
1985	15	11	14	22	22	11	16	17	217	129	17	19
1986	71	16	14	10	7	72	99	33	16	11	10	10
1987	9	7	4	2	1	2	13	12	22	88	249	46
1988	16	21	15	9	8	13	17	15	13	9	14	8
1989	6	5	18	14	11	8	18	19	17	51	24	13
1990	9	9	7	4	3	5	8	23	127	394	88	15
1991	26	30	23	133	123	164	154	133	85	203	43	28
1992	18	18	14	12	8	207	584	1,018	809	576	718	230
1993	313	313	367	278	24	35	22	15	311	658	130	48
1994	53	202	121	95	91	167	317	797	870	525	870	686
1995	264	91	62	154	60	130	216	1,089	724	1,220	242	27
Number of events less than 27 cfs (Total = 206)	**22**	**24**	**25**	**23**	**24**	**19**	**19**	**15**	**9**	**4**	**7**	**15**
Number of events less than or equal to 7 cfs (Total = 45)	**2**	**4**	**5**	**11**	**10**	**5**	**3**	**1**	**1**	**1**	**1**	**1**

a. Average daily cfs
b. Periods when net freshwater flow to the estuary was less than zero are shaded dark gray.

Table 18. Monthly Flows[a] to South Fork as Predicted by 1995 Base Case Conditions[b]

Year	Month											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
1965	15	34	19	16	11	62	34	34	40	131	51	24
1966	103	88	64	45	49	209	172	132	177	306	55	33
1967	27	43	35	17	17	52	75	175	88	357	83	37
1968	24	27	19	15	52	304	254	147	192	324	111	34
1969	38	33	94	29	214	59	43	96	81	179	123	81
1970	128	104	373	146	65	160	71	43	82	206	45	23
1971	20	31	20	14	122	42	83	68	153	89	154	66
1972	40	33	34	69	318	441	163	60	52	65	70	57
1973	64	70	32	25	31	63	134	155	294	184	61	34
1974	55	26	34	19	25	97	254	124	58	97	47	39
1975	23	30	22	16	52	26	49	40	63	72	27	19
1976	16	22	13	19	17	53	34	79	108	40	66	39
1977	40	22	17	15	17	31	40	34	171	117	87	121
1978	48	34	39	26	33	26	40	56	30	37	40	26
1979	22	15	17	25	43	35	20	19	155	70	58	41
1980	29	64	38	20	17	15	14	11	11	10	9	7
1981	9	11	8	6	15	10	18	167	165	56	31	20
1982	19	30	139	117	214	409	263	172	125	129	453	100
1983	83	103	91	55	25	29	19	76	92	230	103	86
1984	80	37	76	42	45	71	26	35	93	53	128	58
1985	24	17	40	52	26	31	80	66	230	83	35	55
1986	124	35	48	44	25	153	88	53	37	25	23	29
1987	23	14	17	11	11	17	35	31	38	141	142	33
1988	30	51	34	21	31	32	78	67	32	20	41	16
1989	14	12	34	39	22	21	60	77	50	88	34	23
1990	19	25	20	14	13	22	26	117	183	177	45	26
1991	106	99	64	194	130	176	123	129	97	170	41	42
1992	26	45	39	34	19	169	117	377	384	223	72	41
1993	221	146	241	145	70	122	66	43	283	479	141	80
1994	108	193	93	125	98	190	224	483	547	274	541	381
1995	128	54	66	106	64	132	134	657	345	795	136	33
Number of events less than or equal to 27 cfs (Total = 95)	**14**	**10**	**10**	**16**	**14**	**7**	**6**	**2**	**1**	**3**	**3**	**9**
Number of events less than or equal to 7 cfs (Total = 2)				**1**								**1**

a. Average daily cfs
b. Periods when net freshwater flow to the estuary was less than zero are shaded dark gray.